Canada Geodetic Service

DEPARTMENT OF THE INTERIOR, CANADA
HON. CHARLES STEWART, Minister — W. W. CORY, C.M.G., Deputy Minister
J. D. CRAIG, Director General of Surveys — NOEL J. OGILVIE, Director, Geodetic Survey of Canada

ANNUAL REPORT

OF THE DIRECTOR

OF THE

GEODETIC SURVEY OF CANADA

FOR THE

FISCAL YEAR ENDING MARCH 31, 1927

1926/27

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1928

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CONTENTS

ILLUSTRATIONS

LINE CUTS

MAPS

51856—1½

THE GEODETIC SURVEY OF CANADA

ANNUAL REPORT OF THE DIRECTOR, NOEL J. OGILVIE

INTRODUCTION

Both the field and the office operations of the Geodetic Survey of Canada undertaken during the year ended March 31, 1927, have been successfully carried out.

Field work was undertaken in all of the nine provinces. The following is a tabular statement of the work accomplished:

Field operation	1926 season	Total to date
	Miles	*Miles*
Completed primary triangulation, length	434	5,016
Completed secondary triangulation, length	52	802
Triangulation begun, reconnaissance completed, length	300	1,233
Precise traverse, length	107	380
Precise levelling	488	22,660
Secondary levelling	47	9,308
	Number	*Number*
Fundamental bench marks	8	23
Standard precise bench marks	199	7,627
Standard secondary bench marks	26	2,917
Base lines	2	21
Laplace stations	1	34
Astronomical stations, other than Laplace stations	7	7

The rapid development of Canada within recent years and the consequent projection and construction of extensive engineering works by municipalities and industrial concerns has created a demand for accurate latitude, longitude and elevation above sea-level of selected points often far removed from industrial centres. The Department of the Interior has met this situation by drawing up a program of work having in view the extension of the levels and triangulation nets of the Geodetic Survey to those parts of the country where the necessity for the information appears to be most urgent. This effort has been appreciated by the municipalities and industries concerned to such an extent that in a number of cases they have made contributions toward the cost of certain local sections of the surveys in order to have the work done in advance of the program.

REVISION OF PUBLISHED ELEVATIONS IN CANADA

In 1906 when the first precise levels were run by this Survey the only available bench marks of which the elevations above mean sea level had been accurately determined were a few near the seaboard, and certain United States bench marks adjacent to the International Boundary. Precise levelling operations were urgently needed simultaneously in different parts of the country and to satisfy these requirements the levelling was started from various initial bench marks. In order that the latest levelling results should be immediately available for public use they were published annually in the form of descriptions and elevations of precise level bench marks as soon as the

information could be compiled at the conclusion of the field operations. The published elevation of each bench mark was designated as "instrumental," being the difference of elevation as determined by field work between it and an initial bench mark. Gradually as the operations extended loops or circuits were formed, each having a circuit closure; also there were discrepancies when the levelling based on one initial bench mark joined that which depended on another. To remove these discrepancies and to ascertain the most probable value of the elevation of any bench mark is a matter of adjustment. The mathematical investigation of field data by the method of least squares ranks equally in importance with the precision of the field operations. Several years ago there was inaugurated a differential adjustment in order to more clearly ascertain the effects of new data which were being added to the precise level net from year to year. By this method of adjustment the comparatively weaker links of the net were determined and then strengthened by revision in the field. The addition of new links to the level net affects the whole but gradually as the weaker links are strengthened the effect becomes less and less until when all parts of the net have reached the same relative strength the effect will be merely local. To illustrate, suppose a line of precise levels is run in the centre of Saskatchewan forming a new link in the net, it is expected that these new data may appreciably affect the elevations of bench marks in that province but will not be noticeable in the elevations of bench marks in either Alberta or Manitoba. It is now felt that the net has reached this stage and that the addition of new lines will have very little appreciable effect on the present adjusted values.

It is fully realized that the engineering public places confidence in values of the elevations and geographic positions as determined and published by the Geodetic Survey of Canada and is prone to consider such as final. If these values are subsequently changed not only is this confidence shaken but in many cases where extensive records of elevations have been based on one precise bench mark a real inconvenience is experienced. On the other hand, the scientist recognizes that there is no absolutely final value attainable and is ever striving to make a closer approximation to the true value. Except in rare cases where the published value of an elevation was subsequently found to be grossly in error, the policy of this Survey has been to leave unchanged the "instrumental" elevations. This policy has been a great convenience to the public and has been largely responsible for the confidence placed in all geodetic determinations. It is proposed to make the first general revision of precise level results in replacing the heretofore published "instrumental" values by the adjusted values. In doing so all discordances existing in the published elevations will disappear. It is confidently anticipated that with rare exceptions these elevations may hold at least until such time as the descriptions of the bench marks will again require revision. In order to show definitely the exact amount of the change effected in elevations a table appears on page 12 showing the old and new values at representative points across the Dominion.

LEVELLING

Field Operations

Somewhat more than half the precise levelling done in the year 1926 consisted in the revision of certain lines run a number of years ago, the object of the revision being to improve the accuracy of these lines and to pave the way for a general adjustment of the precise level net which should hold unchanged for a long period of years. It is a satisfaction to be able to state that all the weak links in the level system have now been strengthened and that as a result the net is in good order for an adjustment which should possess considerable permanence.

During the season five parties were in the field—one in the province of Quebec, occupied in precise and secondary levelling and in special work for the city of Montreal; one in Ontario; two in Manitoba and Saskatchewan, on inspection and levelling revision; and one in British Columbia, engaged partly on new work and partly on revision.

In continuation of the policy inaugurated in 1925 special monuments known as "Fundamental bench marks" were constructed by each of the parties at certain selected points. In the two years, 1925 and 1926, twenty-three of these have been constructed—approximately half being in Ontario and Quebec and half in the West. It is planned to continue their construction on an augmented scale during 1927.

Levelling in the Province of Quebec. The first work undertaken by this party was the extension of the precise level line following the north shore of the St. Lawrence river below the city of Quebec. This line had been run several years ago as far as Ste. Anne de Beaupre and St. Joachim; during the present season it was extended along the Canadian National railway to Murray Bay and to Nairn Falls, on the Murray river. A branch was also run from the village of Beaupre up through the hills to Seven Falls, on Ste. Anne river. It is felt that the precise bench marks established at selected points will greatly facilitate a study of the effects of any future displacements which may occur at any future time.

On the completion of the above work the party moved to Levis and ran secondary levels from that point to Tring Junction, following the Levis-Jackman highway (No. 23) as far as Beauce Junction and thence the Beauce Junction-Sherbrooke highway (No. 5). At each end and at two or three points en route this line was tied to precise level bench marks established about fifteen years ago along the Quebec Central railway. The limit of agreement of forward and backward levelling over each section was set at .030 times the square root of the length of the section (in miles) in place of .017 times, as in precise levelling. A touring car and a motor truck were used for transportation.

At Tring Junction the party was disbanded and the engineer proceeded to Montreal about the middle of August to spend the remainder of the season in the carrying out of special levelling work in the city and surrounding district. Four hundred and fifty-four concrete monuments of a special design (combined bench marks and triangulation stations) had been constructed by the Corporation of Montreal at selected points; these were connected by precise levelling, the loop line, which was extended around the outskirts of the city in 1917, being used as the basis for the new work. A total of 109 miles of double levelling (run both forward and backward) was involved.

The Montreal work was done under the co-operative arrangement previously followed in the city of Quebec, whereby the Corporation paid for the subsistence of the engineer and provided the required assistants, together with automobile transport. Practically the only expense incurred by the Geodetic Survey was the salary of the engineer for the time he was engaged on the special work.

Levelling operations were carried out for a special purpose in the province of Quebec during the months of September and October. A request had been received from the Canadian International Paper Company that the precise level line run up the Gatineau valley some years ago as far as Gracefield, Que., should be continued along the Canadian Pacific railway to Maniwaki and thence northerly along country roads to the Company's Bitobi dam across the Gatineau river. This request was complied with, since the first part of the extension (as far as Maniwaki) was a logical development of the Quebec portion of the level net and would have been undertaken sooner or later in any case. To carry out the work, which took about one month to complete, the Company provided

the personnel of a field party and their subsistence in camp. Immediately on the close of the field work the necessary checking and compiling was completed in the office and the results furnished to the Company.

Levelling in the Province of Ontario. The season's work lay partly in northern and partly in southwestern Ontario, the first line run being along the Algoma Central railway from Hearst southerly to Franz, a distance of 100 miles. In co-operation with the Hydrographic Survey, Department of Marine and Fisheries, the next work undertaken was a precise level connection between lakes Huron and Superior. The Hydrographic Survey installed automatic gauges at Thessalon on the north shore of lake Huron and at Gros cap on the east shore of lake Superior about twelve miles above Sault Ste. Marie, Ont. The Thessalon gauge was connected by precise levelling with the Sudbury-Sault Ste. Marie line, run some years previously, and this line was then extended at its western end to tie in the Gros Cap gauge.

From here the party moved to London and ran precise levels along the London and Port Stanley railway to Port Stanley; at the latter point the Hydrographic Survey's automatic gauge was tied in, thus forming another connection between the Western Ontario precise level system and the water surface records of lake Erie. Finally the Collingwood gauge was connected to the Toronto-Sudbury line of levels by means of a branch line along the Canadian National railway from Alliston.

Levelling in the Province of Saskatchewan.—No new levelling was done in the province of Saskatchewan, the work in hand being the revision of the precise level circuit Moose Jaw-Rosetown-Saskatoon-Regina, which was carried out by two levelling parties. This circuit had an abnormally large closing error and was a source of weakness in the net adjustment. The two longest sides, namely, Rosetown to Moose Jaw and Saskatoon to Regina were completely rerun, with the result that the closure was so much improved that it was not found necessary to revise the other two sides. Extra bench marks were established along the relevelled lines where desirable, and Fundamental bench marks were constructed in the cities of Moose Jaw, Regina and Saskatoon and near the railway junction point at Rosetown. Both of these parties worked a short season, the combined operations aggregating only slightly more than would a full season for one party.

Prior to the organization of one of the above parties the engineer in charge conducted an inspection of the bench marks along certain lines in Manitoba and Saskatchewan. The lines inspected were from Portage la Prairie to Prince Albert, via Dauphin and Swan River; from Prince Albert to Big River; and from Prince Albert to Saskatoon; also along the Hudson Bay railway from Hudson Bay Junction to the end of the precise level line, some 240 miles beyond The Pas, Man.

Levelling in the Province of British Columbia.—About three-quarters of the levelling done in British Columbia in the summer of 1926 was on the circuit Hope-Spences Bridge-Brodie. This circuit was completely rerun and the closure reduced to less than one-third of the former amount. The new work consisted in a line of levels along the Canadian Pacific railway from Kaslo on Kootenay lake to Nakusp on Upper Arrow lake, the levels beginning and terminating at staff gauges maintained by the Public Works Department. This department's gauges at Kootenay Landing, Arrowhead, and Okanagan Landing were also connected, in each case, to the nearest precise level bench mark.

As a result of the work completed this season a useful system of combined precise levels and water transfers now covers the whole southern portion of British Columbia.

Inspection of Bench marks.—In addition to the inspection of bench marks on the prairies, to which reference has already been made, the systematic inspection of bench marks in Eastern Canada by the Supervisor of Levelling was continued. The section covered was in the province of Quebec, north of the St. Lawrence and Ottawa rivers.

The total number of bench marks inspected during the season was 556. It was found that 7½ per cent of this number had been destroyed. The lines covered by the inspection aggregated 1,842 miles and included the relevelled lines, Regina to Saskatoon, Moose Jaw to Rosetown, and Spences Bridge to Brodie.

The following table shows the total number of original bench marks and the percentage of bench marks destroyed since the inception of the systematic bench mark inspection, classified as to age at time of inspection:—

——	Less than 5 years old	5 to 10 years old	10 to 15 years old	15 to 20 years old
Total original number of bench marks in inspected lines	472	812	833	108
Number of bench marks destroyed	0	35	109	31
Percentage destroyed	0	4	13	29

The fact that such a large percentage of the older bench marks has been destroyed is due mainly to the construction of bench mark piers of too light a type and to the placing of other bench marks in structures of a poor class. Those established within the last ten years, it is to be noted, have suffered very little, less than 3 per cent having been destroyed.

Summary of Field Work, 1926

Province	Mileage levelled	Bench mark piers built	Bench marks established
Quebec	250*	1	48
Ontario	174	7	80
Saskatchewan	326	6	52
British Columbia	271	3	27
	1,021	17	207

*This includes the 109 miles run in the city of Montreal and district but the bench marks—454 in number—have not been included in the summary since they are not of the standard type used by this Survey.

Since all the levelling in Saskatchewan and the greater portion of that in British Columbia consisted in a retracement of old lines, the total amount of new levelling added to the precise level net during the year was considerably less than shown above, being 488 miles.

The following is a detailed statement of the precise level lines run in 1926:—

Line	On railway	Off railway	Total
New Levelling	*Miles*	*Miles*	*Miles*
St. Joachim to Murray Bay, Que.	67·4	1·0	68·4
Beaupre to Seven Falls, Que.	0·0	11·1	11·1
Montreal District lines	0·0	109·2	109·2
Gracefield to Maniwaki, Que. and northerly	23·0	38·6	61·6
Hearst to Franz, Ont.	100·0	0·0	100·0
Extensions at Sault Ste. Marie and Thessalon, Ont.	0·0	16·0	16·0
London to Port Stanley, Ont.	20·8	0·0	20·8
Alliston to Collingwood, Ont.	35·0	2·7	37·7
Kaslo to Nakusp, B.C.	63·0	0·0	63·0
	309·2	178·6	487·8
Revision Levelling	*Miles*	*Miles*	*Miles*
Rosetown to Moose Jaw, Sask.	160 4	2·0	162·4
Regina to Saskatoon, Sask.	161·7	1·4	163·1
Spences Bridge to Brodie, B.C.	65·2	0·6	65·8
Spencse Bridge to Hope, B.C.	90·8	0·0	90·8
Hope to Brodie, B.C.	50·6	0·5	51·1
	528·7	4·5	533·2

General Summary

Precise levelling—		
Prior to 1926	22,172 miles	7,443 bench marks.
1926	488 "	207 " "
Total	22,660 "	7,650 " "
Secondary Levelling—		
Prior to 1926	9,261 "	2,891 " "
1926	47 "	26 " "
Total	9,308 "	2,917 " "

The mileage of precise and secondary levelling in each of the provinces is as follows:—

Province	*Precise Levelling*			*Secondary Levelling*		
	Prior to 1926	1926	Total	Prior to 1926	1926	Total
Nova Scotia	729	–	729	–	–	–
New Brusnwick	1,096	–	1,096	–	–	–
Quebec	2,593	250	2,843	–	47	47
Ontario	5,514	175	5,689	–	–	–
Manitoba	2,162	–	2,162	368	–	368
Saskatchewan	3,919	–	3,919	5,098	–	5,098
Alberta	2,866	–	2,866	3,795	–	3,795
British Columbia	2,740	63	2,803	–	–	–
Yukon	458	–	458	–	–	–
Minnesota, U.S.A.	89	–	89	–	–	–
Vermont, U.S.A.	6	–	6	–	–	–
	22,172	488	22,660	9,261	47	9,308

The mileage of *precise levelling* along each of the railways is as follows:—

Railway	*Miles*
Canadian National	11,185
Canadian Pacific	7,306
Kettle Valley	364
Timiskaming and Northern Ontario	320
Algoma Central	319
Alberta and Great Waterways	282
Great Northern	230
Edmonton, Dunvegan and British Columbia	170
Dominion Atlantic	146
Quebec Central	109
White Pass and Yukon	91
Temiscouata	82
New York Central	55
Pere Marquette	55
Boston and Maine	40
Maine Central	36
Roberval-Saguenay	31
Napierville Junction	28
British Columbia Electric	28
Quebec Railway, Light and Power Company	25
London and Port Stanley	24
Alma and Jonquiere	16
Maritime Coal, Railway and Power Company	12
Pacific Great Eastern	9
Michigan Central	3
Highways and cross-country levels	1,694
	22,660

Office Operations

This phase of the work during the year included the incorporation of the current season's field work, the revision of the results of past seasons, the collection and co-ordination of suitable levelling data from various outside sources, and the preparation of new publications. No publication was issued during the year, but a complete revision of the data referring to precise level bench marks has been undertaken. This revision, which includes the whole extent of the precise level net across Canada, comprises two main items, namely, the descriptions of the bench marks and lists of their elevations.

Revised elevations for all bench marks in Eastern Canada will become available early in the coming year through the extension of the detailed adjustment over the eastern lines. This opportunity has been taken to revise completely all the descriptions. It might be thought that a description of a bench mark is not subject to change; as a matter of fact many changes occur. A description becomes out of date after a certain number of years. This is owing to changes in the surroundings and in structures. The description of a certain percentage of the bench marks over a period of time must also be considered; for example, a record that a mark is so many feet from the corner of a building may become out of date with any subsequent addition to the building, or some reference object, from which the distance to a bench mark has been recorded, may be moved or demolished. Where there are many hundreds of bench marks there will necessarily be many cases where the description of a mark calls for revision. At the end of the 1926 season there were 7,650 precise level bench marks distributed over Canada. About one-third of these have never been published in printed form, although many of them have been issued from time to time in typed lists. Another third, nearly all in the eastern provinces, although they have been printed, were yet established so long ago that the need of revised printed descriptions is great, in addition to the fact that the published elevations could not, at the time, be adjusted.

The order followed in this compilation, has been to commence with revision of work in the East, and extend to that of the West. The country is divided into certain districts, and attention is concentrated as much as possible on one district until it is more or less complete, although a certain amount of advance work is kept up at the same time over successive districts.

In the collection and co-ordination of levelling data of outside organizations, the records possessed by railway companies occupy an important place. Here are found the results of many thousands of miles of levelling in which costly field work has been done, but it has not been generally available owing to want of co-ordination, and to the want of convenience in its form of record. If these railway levels are co-ordinated and listed in convenient form, they become valuable for many purposes. The complexity of the work of co-ordination is, however, very great. During the past year the elevations along 2,800 miles of railway have been co-ordinated, listed, and typed in a form convenient for immediate reference or for distribution. The total of such lists ready to be supplied now amounts to 4,500 miles. Nearly all of this railway mileage is in the western provinces, and particular attention has been paid to having all recently constructed railways included. In addition to these completed lists preparatory work has been done upon another 1,000 miles of railway levelling.

Considerable attention has been given to supplying all inquiries for elevations as fully as possible. During the year, apart from supplying printed publications or completely typed lists of various lines of levelling, data along a total of 4,100 miles of levelling have been supplied, in special form, in reply to particular inquiries. These replies have involved about 5,500 separate elevations. There seems little doubt that many more people could be assisted in their needs if it were more generally known that extensive information in regard to elevations is now available.

There is a considerable amount of revision and adjustment of the records of secondary levelling always going on. This is not readily expressed by statistics, but as the precise and secondary levels combined amount to more than 32,000 miles, constant attention is needed to keep the records up to date.

Table showing the Effect of Revision in Precise Elevation

City	B.M.	No. located in	Former elevation	Revised elevation	Change in elevation
			feet	feet	feet
Halifax	387–B	Custom House	21·575	21·575	−0·000
St. John	98–B–2	Post Office	43·185	43·132	−0·053
Moncton	134–B	Post Office	42·350	42·314	−0·036
Sherbrooke	1	Post Office	541·535	541·804	+0·269
Quebec	762–B	Palais Station	22·515	22·382	−0·133
Three Rivers	715–B	Post Office	53·963	53·846	−0·117
Montreal	808	Windsor St. Station	111·834	112·004	+0·170
Ottawa	125–A	Dominion Observatory	277·639	278·051	+0·412
Kingston	141–A	Post Office	275·986	276·300	+0·314
Belleville	157	City Hall	257·005	257·261	+0·256
Whitby	180–A	St. Johns Church	288·846	288·890	+0·044
Toronto	187	City Hall	295·693	295·809	+0·116
Hamilton	199	City Hall	316·428	316·554	+0·126
St. Catharines	207	Post Office	357·298	357·424	+0·126
Niagara Falls	145–F	Post Office	572·578	572·704	+0·126
Brantford	219	C.N.R. Station	707·845	707·974	+0·129
Guelph	92–F	Post Office	1,078·160	1,078·255	+0·095
London	236	Custom House	816·012	816·152	+0·140
Chatham	247–A	Post Office	596·801	596·893	+0·092
Windsor	255	Post Office	599·672	599·764	+0·092
Sault Ste. Marie	632	Post Office	601·930	601·803	−0·127
Port Arthur	93–E	C.N.R. Station	617·119 615·713	616·534	−0·585 +0·821
Winnipeg	2–F–2	Parliament Buildings	770,513	770·954	+0·441
Brandon	376–C	C.N.R. Station	1,262·578	1,262·995	+0·417
Regina	1–D	Post Office	1,895·279	1,895·617	+0·338
Moose Jaw	94–C–2	Post Office	1,786·321	1,786·696	+0·375
Saskatoon	31–D	Post Office	1,590·147	1,590·620	+0·473
Edmonton	59–H	Post Office	2,187·852	2,188·029	+0·177
Calgary	51–D	City Hall	3,427·165	3,427·417	+0·252
Lethbridge	197–C	Post Office	2,975·770	2,976·004	+0·234
Vancouver	2–J	Post Office	53·685	53·867	+0·182
Kamloops	355–C	Court House	1,180·968	1,181·182	+0·214
Prince Rupert	165–H	City Hall	129·671	129·671	+0·000

TRIANGULATION

Excellent progress was made by all of the parties engaged on triangulation during the field season of 1926. Favourable weather prevailed in almost all areas, and contributed very materially to this result. A statement of the work accomplished appears in the table on page 5.

More than usual interest attaches to the triangulation at the head of the bay of Fundy, in the Maritime Provinces, where the closing between two long nets has been completed. Here an important test of the accuracy of the Canadian triangulation has been made possible. There is now a continuous net of primary triangulation about 1,800 miles long, from lake St. Clair in Ontario to the southeastern point of Newfoundland. This chain crosses southern Ontario and follows the St. Lawrence to Gaspé peninsula; thence it follows the coasts of New Brunswick, Prince Edward Island and Nova Scotia to the north end of Cape Breton island, and spans Cabot strait to Newfoundland. It forms the basis of a number of branch chains of triangulation which have been important in the mapping and charting of all of this large area.

Cairn, and Metal Pipe with painted Bands.

This operation closed a loop composed of about 1,300 miles of Canadian triangulation and over 500 miles of United States triangulation through the New England states. The error of closure was $\frac{1}{250,000}$ of the length of the circuit, which indicates a high order of accuracy in the Canadian net.

Other nets on which field work was done in 1926 were largely continuations of those in progress in 1925. Operations were conducted in all provinces except Saskatchewan.

Canadian Conditions Affecting Progress of Triangulation.—From the standpoint of progress of triangulation as affected by physical conditions Canada may be divided into five areas—Eastern Coast, Eastern Central, Prairie, Mountain, and Western Coast.

In the Eastern Coast area fog is a continual hindrance and makes predictions of progress very uncertain. In both the Eastern Coast and Eastern Central sections which extend over the eastern half of Canada the country is rolling and covered with timber which renders the elevation of the instrument by

towers from 10 to 80 feet high a frequent necessity. In these two areas the prevalence of haze also tends to delays. In parts of these areas transportation is sometimes laborious and often a problem. Fifteen stations in a season of five months represents the average maximum that can be expected from a party making angular measurements.

In the Prairie area triangulation may be carried on more quickly than in other areas on account of the ease of transportation and the absence of haze. In 1925 one party completed the angular measurements of a net 250 miles (400 km.) long and occupied 49 stations in a field season of 136 days, operations being permitted on only 80 days.

In the Mountain area the air is very clear; delays here are mostly caused by difficulties of transportation. Ground stations are the rule in this area.

In the Western Coast area fog and rain, as well as the mountainous nature of the country make progress of primary triangulation relatively slow.

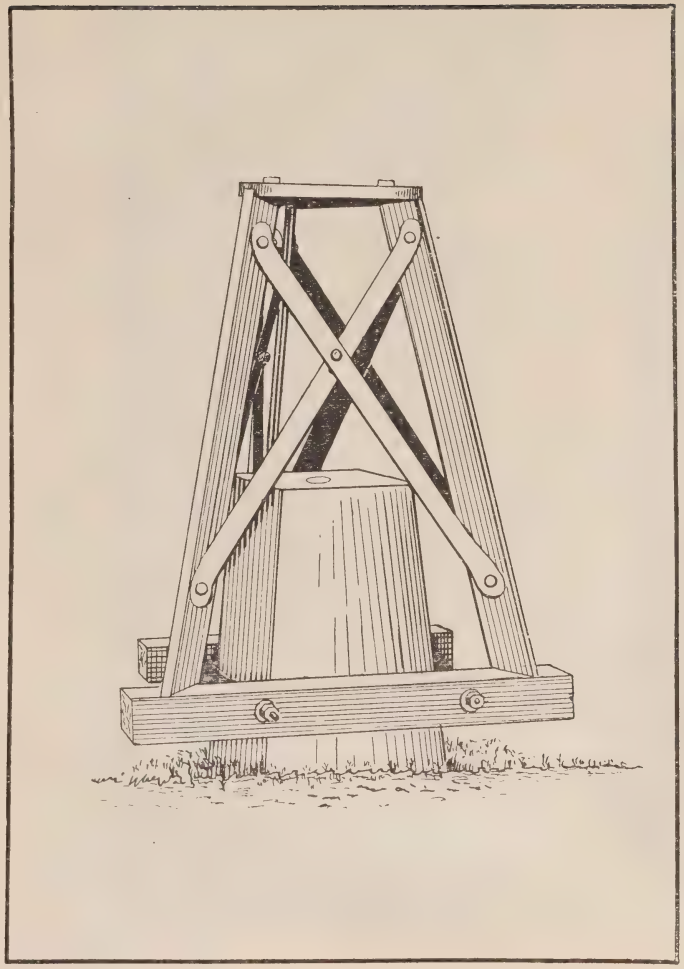
The average length of a field season is 150 days, extending from the middle of May to the middle of October, though as one goes north it may be shortened by two weeks. The maximum is six months which is often attainable in southern Ontario and the prairies.

Secondary Triangulation Signals.—The summits of some mountains are not accessible in the springtime at the opening of operations and in some cases signals designed to withstand the ravages of winter are erected on cairns the previous season. The one shown on page 13 is of galvanized iron piping, so constructed that the sections may be nested for convenience in transport, and bears three bands of black paint at uniform intervals.

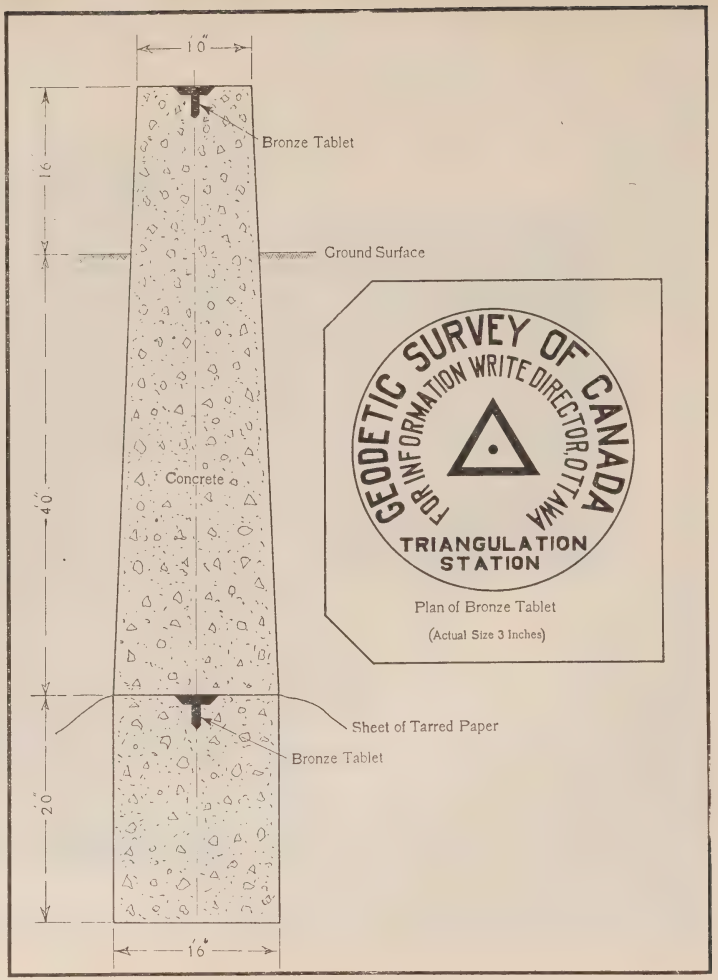
Marking of Triangulation Stations.—When the geodetic survey was begun permanence was taken as the main consideration required in marking triangulation stations. As one means to this end the principle of inconspicuousness was applied. The marks consisted of copper bolts set in concrete placed underground, where there was soil covering, and referenced to concrete monuments placed in convenient fence corners, etc. Where the station occurred on solid rock it was marked by a three-quarter inch copper bolt inserted with its top even with the surface, and was referenced to two or three similar bolts inserted in the rock in convenient and fairly prominent positions.

Difficulties of recovery of stations have demanded a change to a policy of permanence with reasonable conspicuousness. Rock surfaces become quickly overgrown with moss and bush, completely changing the appearance of the ground. At the present time triangulation stations located in bush or where they are not liable to interfere seriously with cultivation of the soil are marked by underground marks consisting of bronze tablets set in concrete below frost line or in solid rock, surmounted by concrete monuments in which bronze tablets are set as illustrated on page 15, where the monument rises a foot or so above the surface.

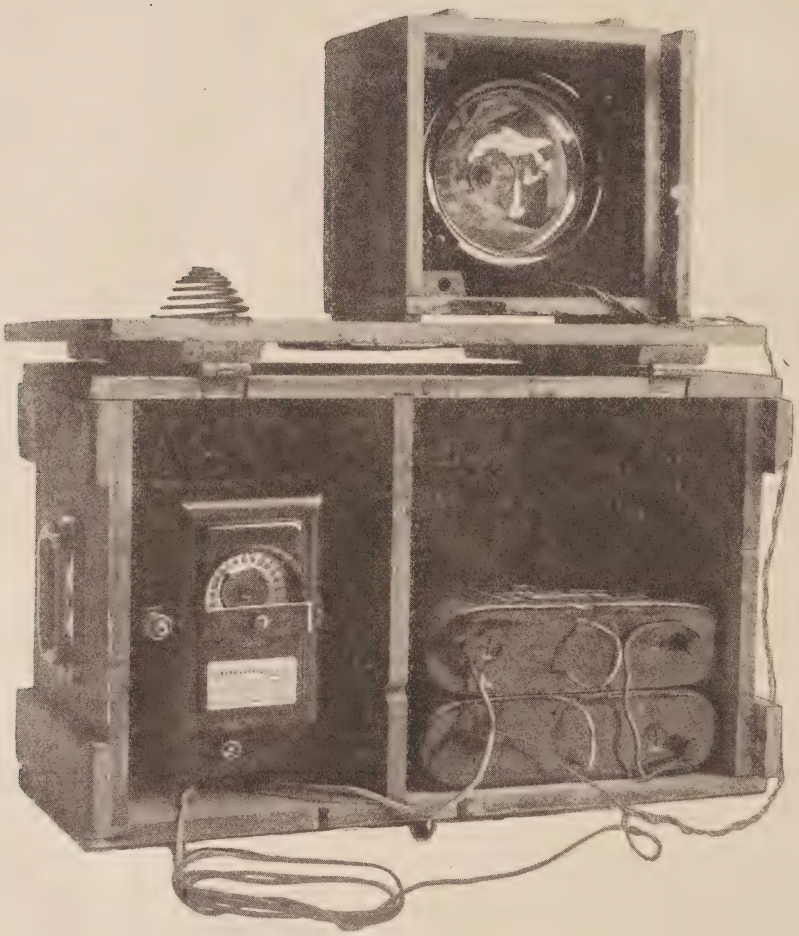
Another aid to permanence is afforded by periodical inspection of triangulation stations, damage or deterioration to the marks being repaired as occasion requires.



Employing Concrete Monument for Instrument Stand.



Concrete Monument for Marking Triangulations.



New Time Switch and Lamp Assembly.—This outfit is now used extensively on primary triangulations to replace seasonally-employed lightkeepers. The time switch turns the light on and off at predetermined times and, where transportation is good, one lightkeeper can tend a number of lamps. The time switch consists of a 40-day clock with switch mechanism; the two batteries each consist of four 1½-volt dry cells connected in parallel; the lamp is a small motor cycle head lamp; the bulb has a rating of 2·5 volts, 0·8 amperes. This small lamp is used on lines up to 25 miles (40 km.) long, and with new batteries needs no attention for a month.

Field Work

MARITIME PROVINCES

Results Obtained.—Area controlled, 4,000 square miles; 11 primary stations established, 11 reoccupied; 6 secondary stations established; 22 intersection stations (lighthouses, church spires, etc.) located; 8 stations re-monumented.

Field operations were carried on in the following areas: Chignecto isthmus, Northumberland strait, that portion of Prince Edward Island west of Charlottetown, and the coastal area southwest of Halifax. The first two areas named were covered by the final link of triangulation between the New Brunswick and Nova Scotia triangulation. A secondary net was completed covering about

Ladder with Lamp-Stand.

300 square miles of the Charlottetown, P.E.I., district. The earlier surveys of this area were made by compass, and map locations based thereon are greatly in error; in one instance an error of about $\frac{3}{4}$ mile in the relative positions of two points less than five miles apart was discovered. The need of triangulation for map revisions here is evident.

Where instrumental observations were not required, an economical substitute for the regular observing tower was employed at certain stations to overcome local obstructions. This consisted of a ladder with lamp stand on top. It was constructed and erected at certain secondary stations, as shown in the illustration on page 17. With modifications of design this idea can be used for ladders 100 feet in height.

Unusually favourable weather prevailed during the whole season.

QUEBEC

Results Obtained.—Reconnaissance, 24 primary stations selected, distance covered 90 miles; direction measurements—17 primary stations completed, distance covered 60 miles.

Two small nets were laid down and completed in the Ste. Anne de Beaupre and the Shawinigan Falls areas, respectively, at the request of the Dominion Observatory, to assist in seismological investigations in these districts. One of the main objects of this work is to obtain, by remeasurement of the angles of the triangulation at some future date, any movements of the earth's crust due to seismic disturbances.

When the field operations on the above nets were completed, work was resumed on the net across the province following the transcontinental line of the Canadian National railway, and a point was reached 25 miles west of La Tuque. This net starts near Three Rivers.

ONTARIO

Results Obtained.—Reconnaissance, 12 primary and 15 secondary stations selected; distance covered, 75 miles; station preparation, 29 stations marked with monuments, 4 reference monuments placed, 4 towers built; angular measurements, 15 primary and 17 secondary stations completed, distance covered 100 miles.

The upper Ottawa River net was extended north through the mining area as far as Cochrane, Ontario, and a small net of secondary triangulation was established along the interprovincial boundary on lake Timiskaming. The need of triangulation in this area has been strongly urged for some years and resultant data have already been usefully employed in map revisions of the mining area.

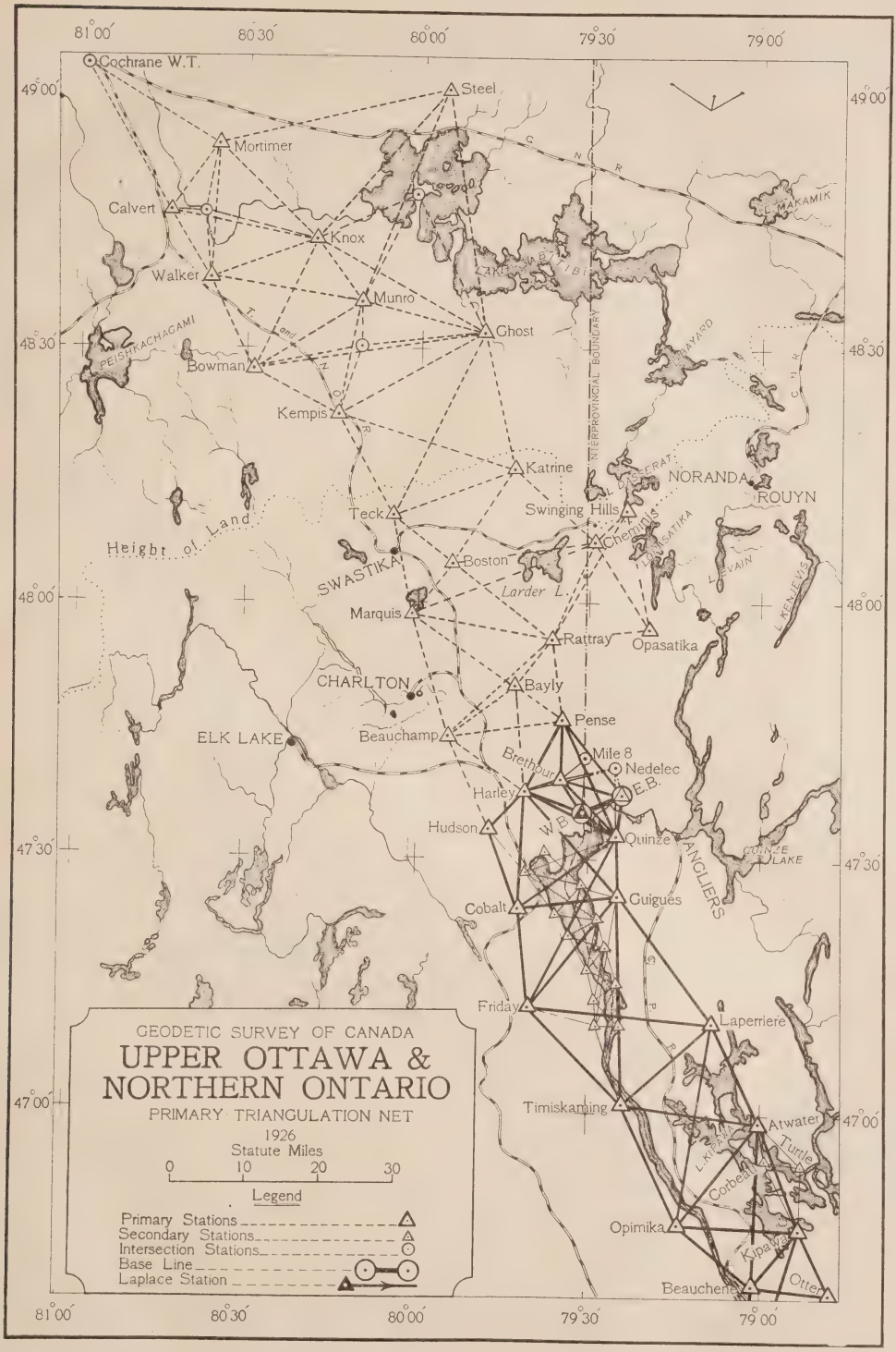
Reconnaissance for the selection of stations was ended for the season at Cochrane, while the angular measurements were completed as far as the north end of lake Timiskaming. Much of the country in which angular measurements were made was very difficult from a transport point of view.

A secondary net of fourteen stations within the primary system was laid down along lake Timiskaming to serve the towns and villages around the lake, since points in these places could not be seen directly from the primary net.

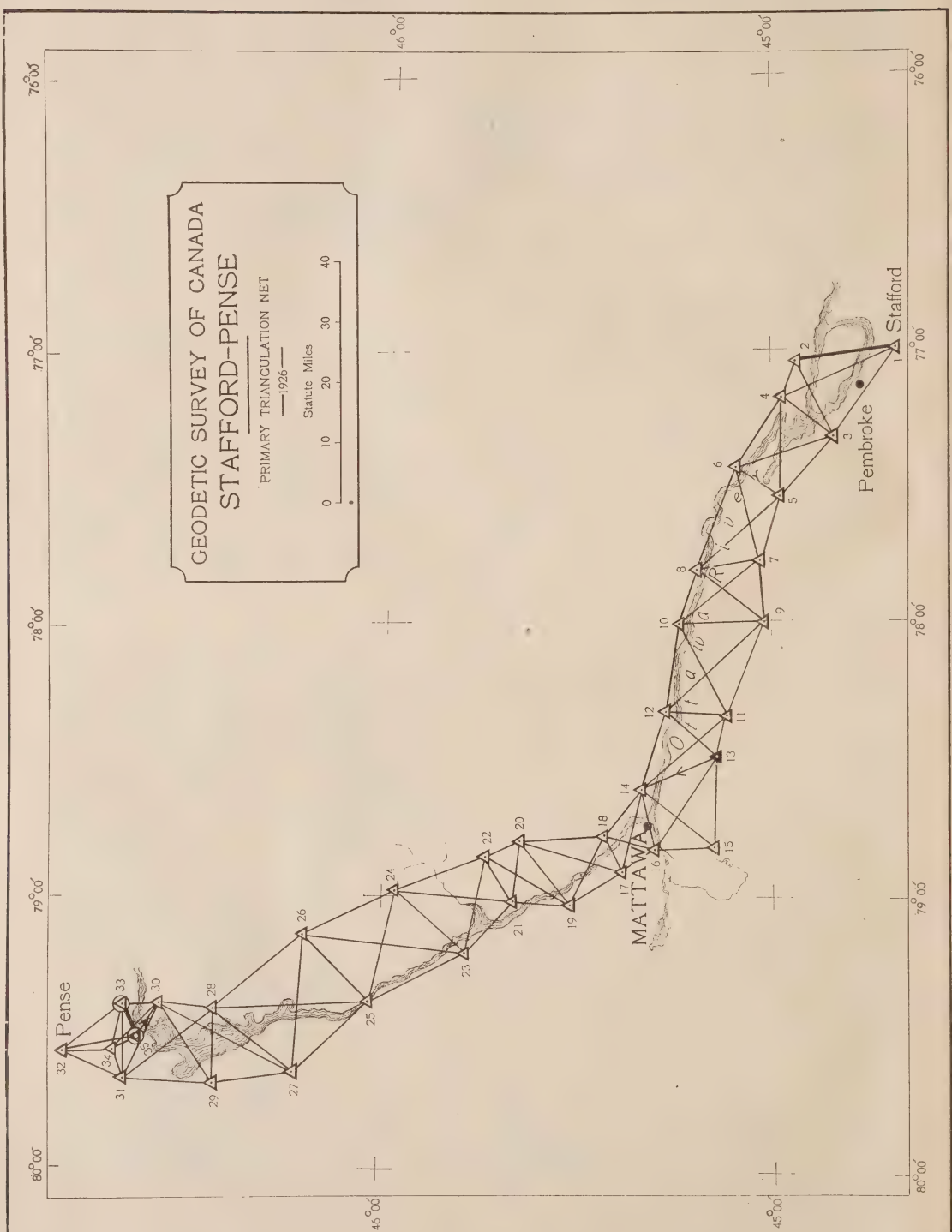
MANITOBA

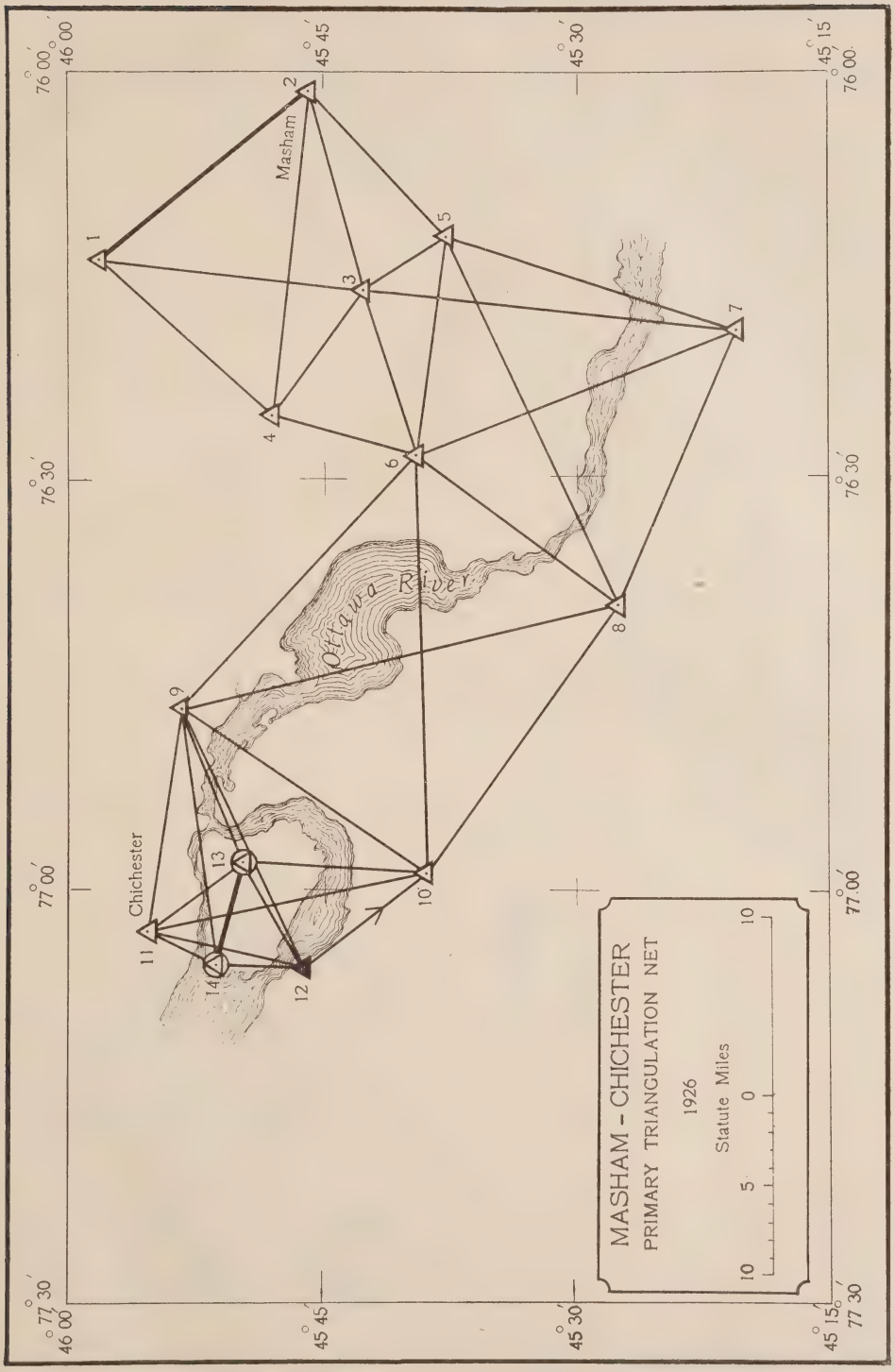
Angular measurements were completed at four northerly stations of a net from the International Boundary north to the vicinity of Brandon, to serve the mapping requirements at Camp Hughes. From main stations of this net a number of points were located for the use of the city engineer of Brandon.

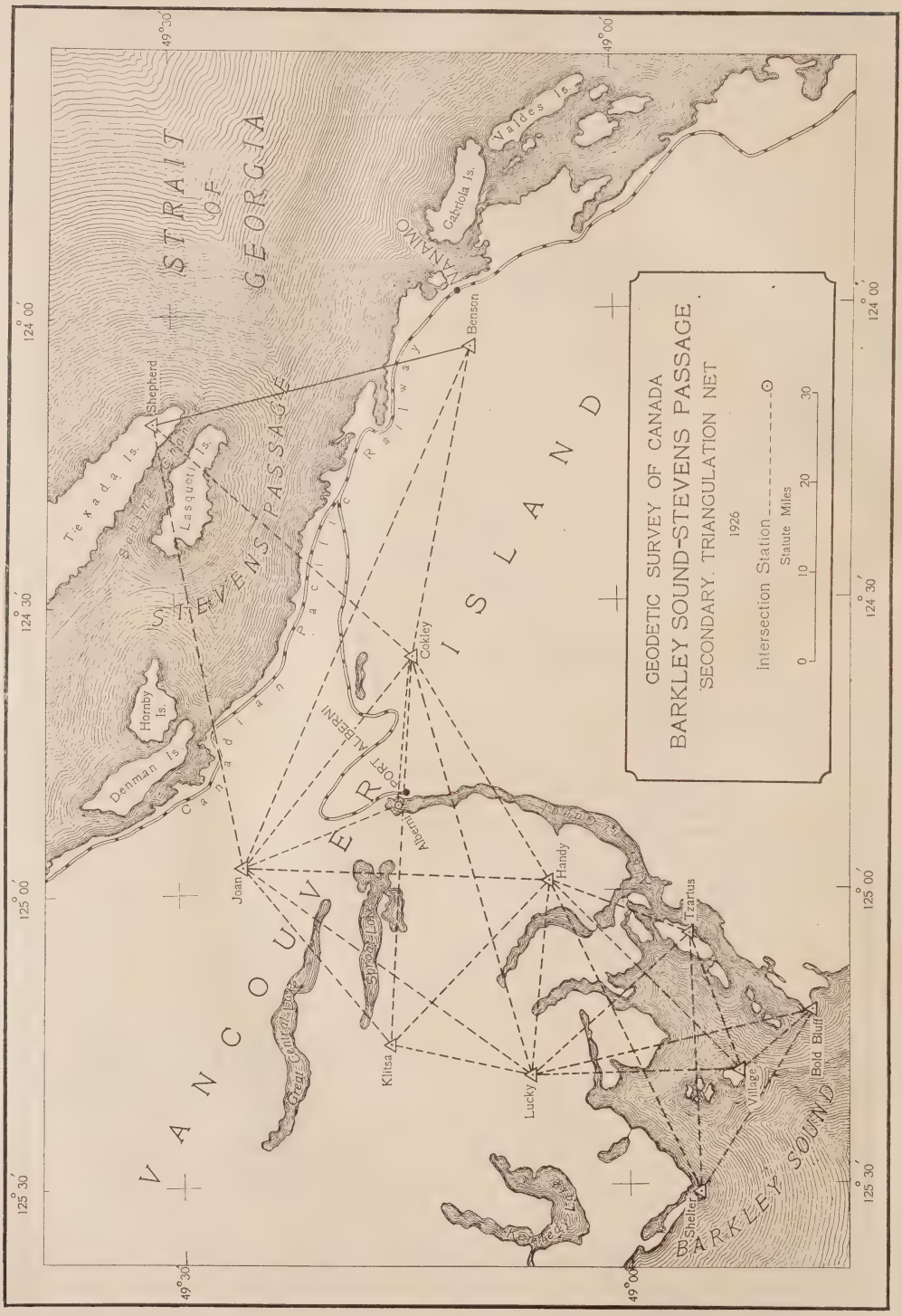
When this work was finished the angle measurement party was moved to the Alberta net.


81°00'
80°30'
80°00'
79°30'
79°00'
49°00'
48°30'
48°00'
47°30'
47°00'
Cochrane W.T.
Steel
Mortimer
Calvert
Knox
Walker
Munro
Ghost
Bowman
Kempis
Katrine
Teck
Swinging Hills
Height of Land
SWASTIKA
Boston
Larder L.
Marquis
Rattray
Opasatika
CHARLTON
Bayly
Pense
ELK LAKE
Beauchamp
Mile 8
Nedelec
Brethour
Harley
E.B.
Hudson
Quinze
Cobalt
Guigues
ANGLIERS
Friday
Laperriere
Timiskaming
Atwater
Turtle
Corbeil
Opimika
Kipawa
Beauchene
Otter
NORANDA
ROUYN
MAKAMIK
PEISTACHAGAMI
ONTARIO-QUEBEC PROVINCIAL BOUNDARY
GEODETIC SURVEY OF CANADA
UPPER OTTAWA &
NORTHERN ONTARIO
PRIMARY TRIANGULATION NET
1926
Statute Miles
0 10 20 30
Legend
Primary Stations
Secondary Stations
Intersection Stations
Base Line
Laplace Station

51856—2½


GEODETIC SURVEY OF CANADA
STAFFORD-PENSE
PRIMARY TRIANGULATION NET
—1926—
Statute Miles
0 10 20 30 40
Stafford
Pembroke
MATTAWA
Pense
Ottawa River
76°00'
77°00'
78°00'
79°00'
80°00'
46°00'
45°00'


MASHAM - CHICHESTER
PRIMARY TRIANGULATION NET
1926
Statute Miles
10 5 0 10
Masham
Chichester
Ottawa River
1
2
3
4
5
6
7
8
9
10
11
12
13
14
77° 30′
46° 00′
77° 00′
76° 30′
76° 00′
45° 45′
45° 30′
45° 15′


GEODETIC SURVEY OF CANADA
BARKLEY SOUND-STEVENS PASSAGE
SECONDARY TRIANGULATION NET
1926
Intersection Station
Statute Miles
0 10 20 30
VANCOUVER ISLAND
STRAIT OF GEORGIA
STEVENS PASSAGE
BARKLEY SOUND
Canadian Pacific Railway
Texada Is.
Shepherd
Lasqueti Is.
Hornby Is.
Denman Is.
Joan
Cokley
Port Alberni
Alberni
Bernson
Nanaimo
Cabriola Is.
Vaudos Is.
Handy
Tzartus
Klitsa
Lucky
Shelter
Village
Bold Bluff
Great Central Lake
Sproat Lake
Kennedy Lake
125° 30′
125° 00′
124° 30′
124° 00′
49° 30′
49° 00′

ALBERTA

Results Obtained.—Reconnaissance, 12 stations selected; distance covered, 52 miles; station preparation, 38 piers built, distance covered, 212 miles; angular measurement, 27 stations completed, distance covered, 190 miles.

The Alberta net was continued during the season. Its course is nothwest from the International Boundary at the 110th Meridian to Calgary, thence north to Edmonton, thence west towards Yellowhead pass.

This net is important from several points of view. At Calgary a number of previous surveys of importance are connected to the triangulation, hence their data can be co-ordinated; at Edmonton the same statement applies, and in addition a triangulation net covering the city has been laid out, which can be completed with little extra work. West of Edmonton several secondary nets will be tied in and their data co-ordinated. The Alberta net will eventually connect with and strengthen the British Columbia triangulation.

Reconnaissance was completed to a point near Edson, about 100 miles west of Edmonton, and a site chosen for a base line along the railway line near Otley, Alberta. Standard piers were built by a special party to a point within 70 miles of where the reconnaissance was completed. Angular measurements were made on the southerly section of the net from the International Boundary almost to Calgary. Lateral refraction, in addition to bad weather and smoke interfered seriously with the progress of this operation.

BRITISH COLUMBIA

Results Obtained.—Precise traverse, 23 permanently marked stations and 498 unmarked traverse stations occupied; distance covered, 107 miles. Secondary triangulation, 11 stations selected; distance covered, 50 miles.

The precise traverse which had been started at Prince Rupert in 1925 and run east about 100 miles along the Canadian National railway was continued in 1926 and reached Smithers, a distance from Prince Rupert of 227 miles. Traverse was substituted for triangulation only because of the great difficulties and expense of triangulation in that area. From Smithers eastward triangulation will be resumed in 1927, the difficult country mentioned above having been passed. This net will eventually be connected to the Alberta net at Yellowhead pass, but for the present it will turn at Prince George and be carried south towards Vancouver through a district of great promise both for minerals and for settlement.

A secondary triangulation net of eleven new stations was laid out in 1926 across Vancouver island from near Nanaimo, B.C., to Barkley sound to serve as a basis for provincial triangulation and hydrographic charting on the west coast of the island. The angular measurements on this net will be made in 1927. A secondary triangulation net, laid down by the Geological Survey, covering the southern part of Vancouver island will be connected to the above net and, since its south end is also based on stations of the Geodetic Survey, the results of this net can be co-ordinated with the primary net and will form a valuable contribution to the geographic data of this area.

GEODETIC ASTRONOMY

The field work in geodetic astronomy consisted of establishing one Laplace station in the Upper Ottawa triangulation and the determination of the longitude and latitude of seven stations in the Upper Gatineau River district.

The Laplace station was at Judge triangulation station in the Upper Ottawa River net. Longitude was observed on seven nights, and the mean time wireless signals from Annapolis were compared with the sidereal clock at the station. In most longitude work the wireless method is used, as it has

two important advantages over the telegraphic method. It is not necessary to select the station in close proximity to a telegraph line, and the work can be done at a greatly reduced expense.

The azimuth observations in connection with this Laplace determination were made on four nights, in thirty-two positions of the horizontal circle. It has become more apparent as experience is gained, that azimuth for Laplace observations should be spread over a number of nights to avoid errors due to lateral refraction. In addition to the longitude and azimuth a primary latitude was also observed.

The longitude and latitude of the seven stations in the Gatineau River district were determined to give control in the survey of the timber limits of the Canadian International Paper Company. The cost of this work was borne by the company, one engineer and his instruments being loaned by the Geodetic Survey of Canada for the field operations. At all these stations the wireless method of obtaining longitude was employed.

BASE LINES

Two base lines, one near Ste. Anne de Beaupre, Quebec, and the other notheast of New Liskeard, Ontario, were measured during the year. The former base was a secondary one to give a scale of length for the small net observed in connection with the earthquake investigation of that area.

The Timiskaming base, about ten miles northeast of New Liskeard, was a primary base to control the scale of the triangulation in the upper Ottawa River triangulation net. This base was about six miles long, and presented no special difficulties. About one-third of the distance was across a swamp. Here great care had to be taken to protect the posts from disturbance during the measurement.

STANDARDS

The invar base line tapes used in the measurement of base lines and also in the precise traverse work were standardized before the season operations began, and also afterwards. In addition the base line tapes were compared with the reference tape in the middle of the summer between the measurements of the two base lines. It is the practice of the Geodetic Survey of Canada to base the lengths of the tapes on the length of the standard metre nickel bar No. 10239. Frequent standardization of the invar base line tapes is necessary.

The invar level rods used in the Precise Level division of the Survey were standardized in the spring and fall. These new level rods are giving splendid satisfaction and are holding their lengths to a very gratifying degree. It is the intention to continue observations on these rods for some time to make sure of their stability.

MATHEMATICAL RESEARCH AND ADJUSTMENTS

Mathematical Research

Geodesy.—A treatise on Geodesy is being published which contains many new propositions and proves in a simpler manner many formulae, the older proofs of which were quite involved and difficult. One of the basic features of the treatise is the relation between the ellipsoid of revolution and the sphere of radius N. This is expressed in the terms of the quantity δ, whereas in older forms the eccentricity e is employed, the relation between these two being that $\delta = \frac{e^2}{1-e^2}$. This equation of the ellipsoid is put in a new form to show that the ellipsoid is tangent to the sphere along a parallel of latitude.

To show the effect of distance, the various formulae, as far as possible, have been developed in powers of $\frac{s}{N}$—the distance and normal—as well as in powers of δ. Thus as many or as few terms as the distance warrants may be employed, and by examination of the δ terms the error of calculations based on the simpler formulae of the sphere may be determined.

Conversion of Latitudes and Departures to True Latitudes and Longitudes, and the Adjustment of First Order Traverses.—The basis of the conversion and of the method of adjustment which has been evolved for traverses is the employment of a fictitious traverse on a plane and the development of the relationship between this traverse and the actual measurements on the earth. The application of Legendre's Theorem to successive polar triangles enables this relationship to be determined and permits of the application of the method of latitudes and departures to the deduction of results.

There are other advantages pertaining to the employment of this method of reduction. One is the facility with which the geodetic position of any individual point on the traverse may be determined by means of its polar co-ordinates, without calculating successively the positions of all intervening points on the traverse. The method also shows the error introduced into the results by treating the traverse as a survey on a plane surface, and provides an easy system of adjusting a traverse between two fixed points.

Research on the Differential Method of Adjustment.—By this method of adjustment any new work, such as the work of a season in triangulation or levelling, or work involving control equations such as Laplace or base equations, may be added to the adjustment of the net as previously existing, without making a complete new adjustment. At the same time the results are the same as if the adjustment had been done as a whole. The effects of the added parts are seen at once, the previous values being left undisturbed and the new added as differentials to the old. By this method also it is possible to divide a very heavy net into a number of smaller nets and later add the parts together, obtaining the same results as if done as a whole.

Mathematical Adjustments

The adjustment of the triangulation nets progressed satisfactorily during the year, and the increasingly large number of requests for triangulation data which the Survey has been able to meet indicates the extent to which this information is being utilized.

The adjustments have been brought as nearly as possible up to date and preliminary geographic positions (latitude, longitude, asimuth and distances) were calculated for as many as possible of the points at which the field work had been completed.

The primary triangulation which extends from Anticosti island along Chaleur bay and the coast of New Brunswick connecting with the Bay of Fundy net has been adjusted, and positions of the numerous points involved made possible.

Preliminary geographic positions of stations and lighthouses in the vicinity of St. Paul island and the north end of Cape Breton island have been calculated and supplied to the Hydrographic Survey for use in the calibration of the radio direction finding station on St. Paul island.

Positions have been calculated for points in the small nets in the Ste. Anne de Beaupre and Shawinigan Falls districts of Quebec and have been used by the Topographical Survey, Department of the Interior, in mapping these areas.

The initial work in connection with the adjustment of the triangulation net from Three Rivers, Quebec, north towards La Tuque has been done. The adjustment of this net is about complete.

The Ottawa River net has been adjusted as far as the north end of lake Timiskaming and the results utilized in the construction of a new map of northern Ontario by provincial authorities.

Traverse Adjustment.—The adjustment of the precise traverse in northern British Columbia east of Prince Rupert has been continued to the point near Smithers, B.C., reached by the field work in 1926. The establishment of a number of Laplace stations will make possible the completion of the adjustment. The method of adjustment is that outlined above regarding the conversion of latitudes and departures into latitudes and longitudes.

Precise Levelling Adjustment.—During the first few months of the fiscal year adjusted elevations of all junction points in the Canadian precise level net were obtained, based on all field work completed to the end of the 1925 season. Later, all 1926 field work was prepared for incorporation into the level net adjustment, and this adjustment carried along.

Triangulation Data.—Filing and indexing of 1926 field data and those resulting from the adjustment of nets, together with the handling of the increasingly large number of requests for information has kept this division very busy during the year. Where information of this nature has not already been put in shape for use, adjustments and calculations are made to supply the demand. Final data for publication of completed results, chiefly in connection with the British Columbia Coast triangulation have been compiled and, where incomplete, have been calculated.

MATERIAL FOR THE THIRD GENERAL CONFERENCE OF THE INTERNATIONAL GEODETIC AND GEOPHYSICAL UNION

In addition to the preceding, a considerable amount of material has been prepared and sent to the Third General Conference of the International Geodetic and Geophysical Union, which is to be held in September of this year at Prague. This material comprises a summary of the amount of work done by this Survey since the last meeting of the Union in 1924, as well as a statement indicative of the precision of the work. The data derived and sent in the case of the levelling were obtained from the closings of the circuits or polygons and from the discrepancies between the forward and backward levelling, in triangulation from the closures of triangles, and in the base line measurements from the discrepancies existing after measurement as well as from a function equation coming from the adjustment.

LIST OF PUBLICATIONS OF THE GEODETIC SURVEY OF CANADA

Publication No. 1—Precise Levelling—Certain lines in Quebec, Ontario and British Columbia.
Publication No. 2—Adjustment of Geodetic Triangulation in the provinces of Ontario and Quebec.
Publication No. 3—Determination of the Lengths of Invar Base Line Tapes from Standard Nickel Bar No. 10239.
Publication No. 4—Precise Levelling—Certain Lines in Ontario and Quebec.
Publication No. 5—Field instructions to Geodetic Engineers in charge of Direction Measurement on Primary Triangulation.
Publication No. 6—(Withdrawn from publication, as levelling contained is republished in Bulletins).
Publication No. 7—Geodetic Position Evaluation.
Publication No. 8—Field instructions for Precise Levelling.
Publication No. 9—The Making of Topographical Maps of Cities and Towns, the First Step in Town Planning.
Publication No. 10—Instructions for Building Triangulation Towers.
Publication No. 11—Geodesy.
Publication No. 12—Mathematical Statistics of the Geodetic Survey of London, Ont. (Distributed by the City Engineer at London, Ont.)
Publication No. 13—Errors of Astronomical Positions Due to Deflection of the Plumb Line.

Publication No. 14—Levelling. Co-ordination of Elevations of Bench Marks in the City of Calgary, Alberta.

Publication No. 15—Levelling. Bench Marks Established along Meridians, Base Lines and Township Outlines in Saskatchewan.

Instructions to Lightkeepers; Use of Electric Signal Lamps being Appendix No. 4 to Publication No. 5.

The Geodetic Survey of Canada; Operations, April 1, 1912, to March 31, 1922—Publications of the International Geodetic and Geophysical Union, Rome, 1922.

Reports of the Section of Geodesy; The International Geodetic and Geophysical Union. Second General Conference, Madrid, 1924; Operations of the Geodetic Survey of Canada: April 1, 1922, to March 31, 1924.

Reports of the Section of Geodesy, The International Geodetic and Geophysical Union, Third General Conference, Prague, 1927, Operations of the Geodetic Survey of Canada, April, 1924, to December, 1926.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1918.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1919.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1920.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1921.

Annual Report of the Superintendent of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1922.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1923.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1924.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1925.

Annual Report of the Director of the Geodetic Survey of Canada for the Fiscal year ending March 31, 1926.

Annual Report of the Director of the Geodetic Survey of Canada for the fiscal year ending March 31, 1927.

Precise Levelling Bulletins

Bulletin A—
Vancouver, B.C., and adjacent district—as far east as Mission, Matsqui and Huntingdon.

Bulletin B—
Abbotsford to Resplendent, B.C.
Spences Bridge to Brodie, B.C.
Mission to Hope, B.C.

Bulletin C—
Saskatoon, Sask., to Prince George, B.C.
Prince Rupert to Prince George, B.C.

Bulletin D—
Calgary, Alta., to Kamloops, B.C.
Revelstoke to Arrowhead, B.C.
Sicamous to Okanagan Landing, B.C.

Bulletin E—
Kipp, Alta., to Golden, B.C.
Bull River to Kootenay Landing, B.C.

Bulletin F—
Calgary to Lethbridge, Alta.
Calgary to Tofield, Alta.
Camrose to Wetaskiwin, Alta.

Bulletin G—
Moose Jaw, Sask., to Coutts, Alta.
Swift Current, Sask., to International Boundary.

Bulletin H—
Irricana to Medicine Hat, Alta.
Bassano, Alta., to Swift Current, Sask.
Empress to Compeer, Alta.
Kerrobert to Unity, Sask.

Bulletin I—
Stephen, Minn., to Regina, Sask.
Regina to Prince Albert, Sask.

Bulletin J—
Napinka to Neepawa, Man.
Minnedosa, Man., to Regina, Sask.
Yorkton to Saskatoon, Sask.
Colonsay to Prince Albert, Sask.
Lanigan, Sask., to Brandon, Man.
Bulletin K—
Emerson, Man., to Port Arthur, Ont.
Sprague to Neepawa, Man.
Portage-la-Prairie to Plum Coulee, Man.
Bulletin L—
Winnipeg, Man., to Kenora, Ont.
Winnipeg to Victoria Beach, Man.
Bulletin M—
Rennie, Man., to Armstrong, Ont.
Superior Junction to Rowan, Ont.
Bulletin N—
Sudbury to Cochrane, Ont.
Armstrong to Cochrane, Ont.
Index Bulletin, Precise Levelling.
Precise Level Lines of the Geodetic Survey of Canada in the provinces of British Columbia, Alberta, Saskatchewan, and Manitoba, and in the northern Portion of the province of Ontario, north and West of North Bay.

Copies of the above publications may be obtained by applying to the Director of the Geodetic Survey of Canada, Ottawa.

PHOTO-LITHOGRAPHED AT THE TOPOGRAPHICAL SURVEY OF CANADA, OTTAWA

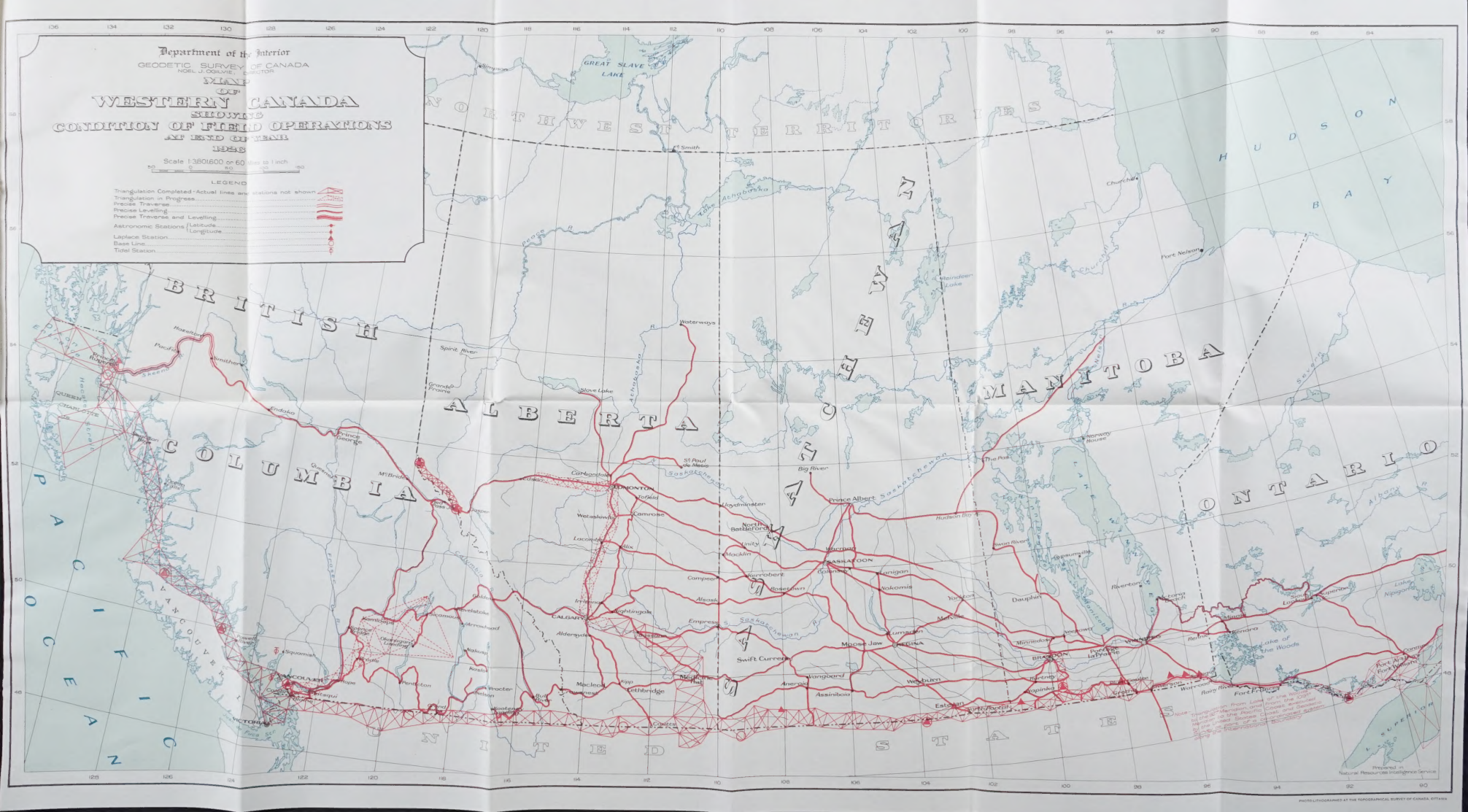


PHOTO-LITHOGRAPHED AT THE TOPOGRAPHICAL SURVEY OF CANADA, OTTAWA